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None

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H4J

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(54) Sound reproduction system

(57) A microphone (10) is acoustically coupled to receive sound from an earphone transducer (14) and sound cancellation feedback is provided by a loop between the microphone (10) and transducer (14). This loop includes a first mixing amplifier (16), a high gain phase-inverting amplifier (12) and a second mixing amplifier (18). Speech signal is introduced via each of the mixing amplifiers (16 & 18) and is such therefore that speech is still discernible in the event of failure of the microphone (10), the first mixing amplifier (16) or the inverting amplifier (12). Each mixing amplifier (16 and 18) may be preceded by an equalisation filter (24, 26) and boost amplifier (20, 22) lying in the speech signal paths. The first mixing amplifier (16) and the inverting amplifier (12) can be arranged for suppressing signal in the event of high level noise transients whilst speech signal can still be introduced via the second mixing amplifier (18).

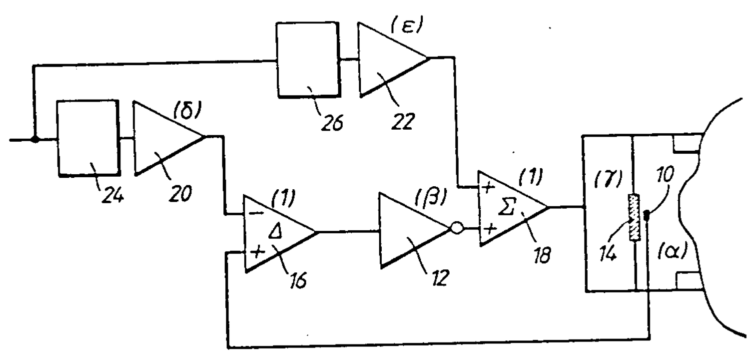

FIG.4.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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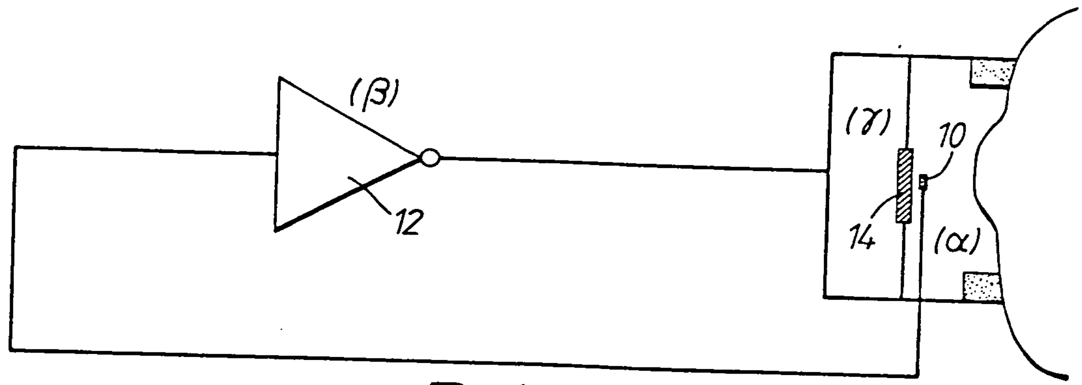

FIG.1.

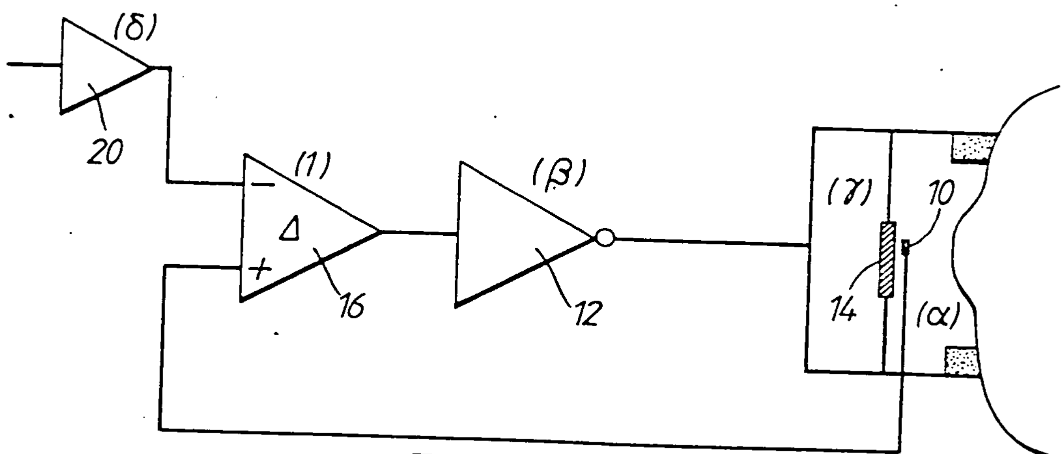

FIG.2.

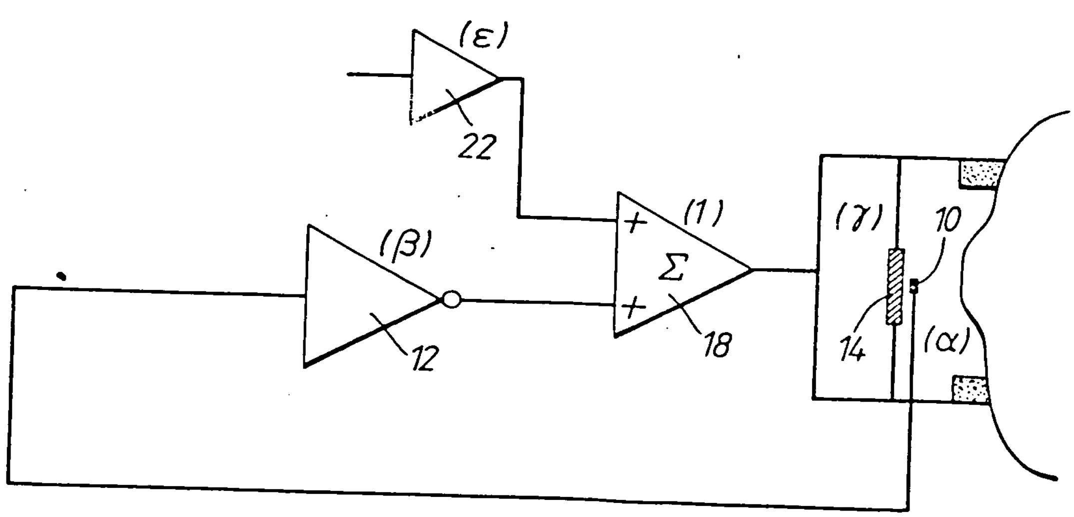

FIG.3.

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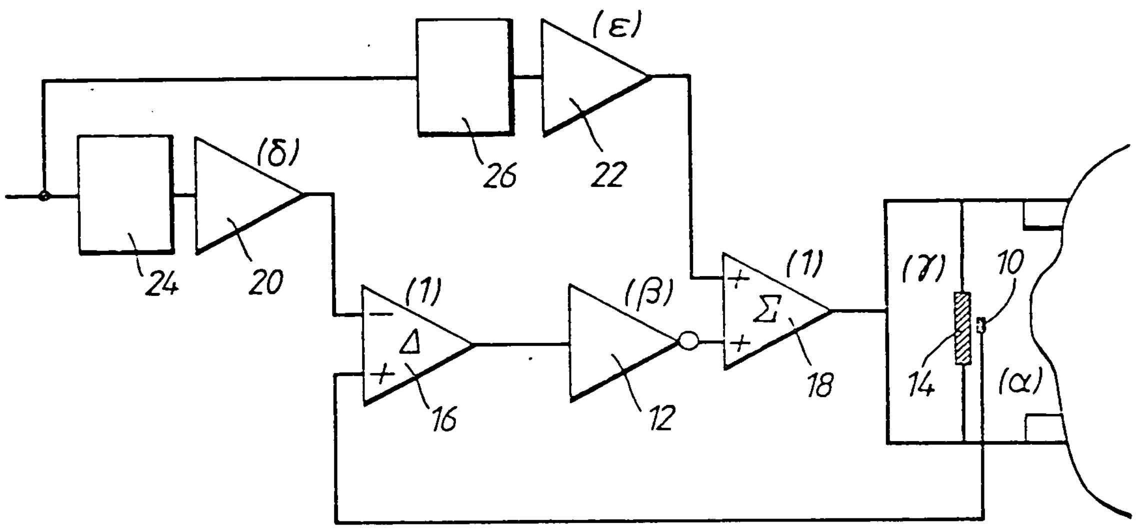

FIG.4.

SPECIFICATION

Improvements in or relating to sound reproduction systems

The present invention relates to sound reproduction systems and more particularly to the reduction of acoustic noise in such systems.

An active noise reduction (ANR) system is one in which the ambient sound field is detected using a sensing microphone and the phase inverted sound signal (i.e. the same sound field with a Π phase change) generated to destructively interfere with the original sound field, which reduces the sound pressure level. This type of noise reduction system is termed "active" as the noise level is reduced by generating sound: this is very different to "passive" noise reduction systems which rely on acoustic absorption to decrease the sound pressure level.

It is an object of the present invention to provide an active noise reduction system which allows the noise level to be reduced and the speech signal to noise ratio to be increased. If any part of most of the ANR system fails, the ANR system will effectively be turned off and under these circumstances speech would still be heard as in a present day communication system.

According to the present invention there is provided a sound reproduction system comprising:
an earphone transducer;
a microphone acoustically coupled to said transducer, being arranged thus to receive sound therefrom; and,
a feedback loop connected between said microphone and said earphone transducer;
wherein said feedback loop includes:
a first mixing amplifier connected to the microphone;
a high gain inverting amplifier connected to the output of this first mixing amplifier; and,
a second mixing amplifier connected to the output of this inverting amplifier;
first and second mixing amplifiers being connected at respective inputs to a speech signal line.

Since speech signal is introduced via two paths, speech can still be discerned in the event of failure of the part of the system that includes the microphone, first mixing amplifier and inverting amplifier.

It is preferable that the speech signals introduced via the first and second mixing amplifiers sum constructively ie. are additive. To this end the first mixing amplifier can be a differential amplifier and the second mixing amplifier, a summing amplifier. In this case speech signal via the first mixing amplifier is substracted from noise signal and then inverted by the inverting amplifier and added to further speech signal by the summing amplifier. It will be appreciated that these two mixing amplifiers can be exchanged to produce equivalent effect.

It is possible to introduce equalisation filters in the speech signal path so that the speech signal will not be distorted and will have an amplitude response "uncoloured" by the system.

Also it can be arranged that the first mixing amplifier and/or the inverting amplifier suppress inordinately large level noise singal. The speech signal can be still heard without distortion.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings in which:-

Figure 1 shows a known active noise reduction (ANR) system.

Figure 2 and *3* show known active noise reduction systems with speech addition.

Figure 4 shows an active noise reduction system with speech addition according to the present invention.

The basic principle of an ANR system is shown in Figure 1. A microphone 10 detects the ambient sound and sends the electrical signal to a phase inverting amplifier 12. The output is fed back to an earphone 14 where the generated sound destructively interferes with the ambient sound to reduce the sound level over a wide frequency bandwidth.

The following symbols are defined:-
N_o is the noise pressure;
N is the total sound pressure, noise plus generated noise, in the earphone;
α is the electro-acoustic transfer function of the microphone;
β is the gain of the phase inverting amplifier; and
γ is the electro-acoustic transfer function of the sound generator.

The self consistent equation is:-

$$N = N_o - \alpha\beta\gamma N$$

$$N = \frac{N_o}{(1+\alpha\beta\gamma)}$$

It can clearly be seen that to achieve beneficial amounts of active noise reduction the loop gain ($\alpha\beta\gamma$ product) needs to be large.

Figures 2 and 3 show known ANR systems with speech addition.

Figure 2 is similar to Figure 1 except that the speech signal after being amplified by a boost amplifier 20 is added to a mixing amplifier 16.

The following symbols are defined:-

S_o is the total signal pressure level in the earphone 14;

V is the signal voltage introduced; and,

δ is the gain of boost amplifier 20.

The self consistent equation is:-

$$N+S_o = N_o - \alpha\beta\gamma\,(N+S_o) + \delta\gamma V\beta$$

therefore $N = \dfrac{N_o}{(1+\alpha\beta\gamma)}$

and $S_o = \dfrac{\delta V\beta\gamma}{(1+\alpha\beta\gamma)}$

In this case the noise and the speech signal have not been reduced by the same amount so that the signal to noise ratio is

$$\frac{\delta V\beta\gamma}{N_o}.$$

As the noise has been reduced, the gain of the boost amplifier 20 could be increased to increase the signal to noise ratio whilst maintaining the reduce noise level, without an excessive sound level being generated in the earphone 14 which would be dangerous to the ear.

Figure 3 shows another ANR system with speech addition. This system has the inverting amplifier 12 first in the loop before a mixing amplifier 18.

The following symbol is defined:-

ε is the gain of amplifier 22.

The self consistent equation is:-

$$N+S_o = N_o - \alpha\beta\gamma\,(N+S_o) + \varepsilon\gamma\,V$$

$$N = \frac{N_o}{(1+\alpha\beta\gamma)}$$

and $S_o = \dfrac{\varepsilon\gamma\,V}{(1+\alpha\beta\gamma)}$

In this case the noise and speech signal have been reduced by the same amount so that the signal to noise ratio is

$$\frac{\varepsilon\gamma V}{N_o}.$$

If the system is inoperative the signal to noise ratio is also the same. However because both the signal and the noise have been reduced, the gain ε may be increased so that the signal to noise ratio is increased without excessive sound being generated by the earphone 14.

Figure 4 is a diagram of a circuit that has been modified in accordance with this invention. Noise in the earphone 14 is sensed by the microphone 10 and the electrical signal connected to a first mixing amplifier, in this example a differential amplifier 16. the output is connected to the phase inverting amplifier 12, and the output of this connected to a second mixing amplifier, in this example, a summing amplifier 16. The output to the earphone transducer 14. The speech signal passes through a boost amplifier 20 to differential amplifier 16 and also through a boost amplifier 22 to summing amplifier 18.

The self consistent equation is:-

$$N+S_o = N_o - \alpha\beta\gamma\,(N+S_o) + \delta\beta\gamma\,V+V\,\varepsilon\gamma$$

$$N = \frac{N_o}{(1+\alpha\beta\gamma)}$$

$$S_o = \frac{V\gamma\,(\delta\beta + \varepsilon)}{(1 + \alpha\beta\gamma)}$$

When the system is operating β is large. $\delta\beta$ is made large compared to ε and then the speech signal introduced into the differential amplifier 16 will become dominant as compared to that introduced into the mixing amplifier 18 for producing speech in the earphone 14. Under these conditions a filter 24 is inserted before boost amplifier 20 which allows the speech signal in the earphone 14 to have the required amplitude response (uncoloured).

If the system is switched off, or any part of items 10, 16 or 12 fail, then speech will still be heard in the earphone via route 22, 18. Under these conditions, setting $\beta = 0$ it follows that $S_o = V\gamma\varepsilon$. In order to allow the speech signal to have the required amplitude response (uncoloured) a filter 26 is inserted before amplifier 22.

The whole circuit is shown in Figure 4 with both filters present, the important speech path being 20, 16 if the gain is high and 22, 18 if the gain is zero.

Additionally, if the voltage rails of inverting amplifier 12 or mixing amplifier 16 are arranged to be less than those of mixing amplifier 18, then if a large signal is sent by the microphone 10 the signal will "clip" on amplifiers 16, 12 resulting in reduced - active noise reduction but the speech will still be heard in the earphone via amplifiers 22, 18 all-be-it at a lower level.

The advantages of this invention are:-

1. In the event of failure of any of the items 10, 16 or 12 the speech signal will still be heard clearly due to its introduction through amplifiers 22 and 18.

2. If the circuit is arranged so that the rail voltages of amplifiers 12 or 16 are less than amplifier 18, the speech signal will still be heard even if an inordinately large signal is sent from the microphone 10.

This invention may be used in any closed loop feedback ANR system to introduce speech and to achieve a large signal to noise ratio, at a reduced noise level irrespective of the design or type of the sound generator or microphone.

CLAIMS

1. A sound reproduction system comprising:-
an earphone transducer;
a microphone acoustically coupled to said transducer, being arranged thus to receive sound therefrom; and,
a feedback loop connected between said microphone and said earphone transducer;
wherein said feedback loop includes:
a first mixing amplifier connected to the microphone;
a high gain inverting amplifier connected to the output of this first mixing amplifier; and,
a second mixing amplifier connected to the output of this inverting amplifier,;
first and second mixing amplifiers being connected at respective inputs to a speech signal line.

2. A system, as claimed in claim 1, wherein speech signals introduced via first and second mixing amplifiers are additive.

3. A system, as claimed in claim 2, wherein one of the mixing amplifiers is a differential amplifier, and the other mixing amplifier is a summing amplifer.

4. A system, as claimed in claim 3, wherein said first mixing amplifier is a differential amplifier.

5. A system, as claimed in any one of the preceding claims, wherein one or both mixing amplifiers are each proceded by an equalisation filter interposed in the speech signal line.

6. A system, as claimed in claim 5, wherein each mixing amplifier is preceded by a respective equalisation filter and boost-amplifier.

7. A system, as claimed in any one of the preceding claims, wherein the first mixing amplifier, or the inverting amplifier, or both, are arranged for the suppression of inordinately large signal.

8. A sound reproduction system, constructed, adapted, and arranged to perform, substantially as described hereinbefore, with reference to, and as shown in Figure 4 of the accompanying drawings.

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RAPPORT DE RECHERCHE INTERNATIONALE

Demande internationale N° PCT/FR 87/00056

I. CLASSEMENT DE L'INVENTION (si plusieurs symboles de classification sont applicables, les indiquer tous) [7]

Selon la classification internationale des brevets (CIB) ou à la fois selon la classification nationale et la CIB

CIB^4: G 10 K 11/16; A 61 F 11/02

II. DOMAINES SUR LESQUELS LA RECHERCHE A PORTÉ

Documentation minimale consultée [8]

Système de classification	Symboles de classification
CIB^4	G 10 K; A 61 F; H 04 R

Documentation consultée autre que la documentation minimale dans la mesure où de tels documents font partie des domaines sur lesquels la recherche a porté [9]

III. DOCUMENTS CONSIDÉRÉS COMME PERTINENTS [10]

Catégorie *	Identification des documents cités, [11] avec indication, si nécessaire, des passages pertinents [12]	N° des revendications visées [13]
A	US, A, 4494074 (BOSE) 15 janvier 1985, voir colonne 2, ligne 60 - colonne 4, ligne 9; figures 1,2 cité dans la demande --	1
A	GB, A, 2160070 (PLESSEY) 11 décembre 1985, voir abrégé; figures 1-3 cité dans la demande --	1
A	DE, A, 2925134 (SENNHEISER ELECTRONIC KG) 8 janvier 1981, voir page 5, lignes 25-30; figures 2,4 cité dans la demande ---------	1

* Catégories spéciales de documents cités: [11]

« A » document définissant l'état général de la technique, non considéré comme particulièrement pertinent

« E » document antérieur, mais publié à la date de dépôt international ou après cette date

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« X » document particulièrement pertinent: l'invention revendiquée ne peut être considérée comme nouvelle ou comme impliquant une activité inventive

« Y » document particulièrement pertinent: l'invention revendiquée ne peut être considérée comme impliquant une activité inventive lorsque le document est associé à un ou plusieurs autres documents de même nature, cette combinaison étant évidente pour une personne du métier.

« & » document qui fait partie de la même famille de brevets

IV. CERTIFICATION

Date à laquelle la recherche internationale a été effectivement achevée	Date d'expédition du présent rapport de recherche internationale
17 juin 1987	16 JUIL 1987
Administration chargée de la recherche internationale	**Signature du fonctionnaire autorisé**
OFFICE EUROPEEN DES BREVETS	M. VAN MOL

ANNEXE AU RAPPORT DE RECHERCHE INTERNATIONALE RELATIF

A LA DEMANDE INTERNATIONALE NO. PCT/FR 87/00056 (SA 16414)

La présente annexe indique les membres de la famille de brevets relatifs aux documents brevets cités dans le rapport de recherche international visé ci-dessus. Lesdits membres sont ceux contenus au fichier informatique de l'Office européen des brevets à la date du 25/06/87

Les renseignements fournis sont donnés à titre indicatif et n'engagent pas la responsabilité de l'Office européen des brevets.

Document brevet cité au rapport de recherche	Date de publication	Membre(s) de la famille de brevets	Date de publication
US-A- 4494074	15/01/85	Aucun	
GB-A- 2160070	11/12/85	Aucun	
DE-A- 2925134	08/01/81	Aucun	

Pour tout renseignement concernant cette annexe :
voir Journal Officiel de l'Office européen des brevets, No. 12/82

INTERNATIONAL SEARCH REPORT

International Application No PCT/FR 87/00056

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [8]

According to International Patent Classification (IPC) or to both National Classification and IPC

CIB^4 : G 10 K 11/16; A 61 F 11/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
CIB^4	G 10 K; A 61 F; H 04 R

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	US, A, 4494074 (BOSE) 15 January 1985, see column 2, line 60 - column 4, line 9; figures 1,2, cited in the application --	1
A	GB, A, 2160070 (PLESSEY) 11 December 1985, see abstract; figures 1-3 cited in the application --	1
A	DE, A, 2925134 (SENNHEISER ELECTRONIC KG) 8 January 1981, see page 5, lines 25-30; figures 2,4 cited in the application	1

* Special categories of cited documents: [10]
- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
17 June 1987 (17.06.87)	16 July 1987 (16.07.87)
International Searching Authority	**Signature of Authorized Officer**
European Patent Office	

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/FR 87/00056 (SA 16414)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 25/06/87

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4494074	15/01/85	None	
GB-A- 2160070	11/12/85	None	
DE-A- 2925134	08/01/81	None	

For more details about this annex :
see Official Journal of the European Patent Office, No. 12/82